



Probable Levels of R&D Expenditures in 1983

Forecast and Analysis

This report, from the Columbus Division of Battelle Memorial Institute, is based upon a continuing study of U.S. expenditures for research and development. It was prepared in the Applied and Technical Economics Department by Drs. Jules J. Duga and W. Halder Fisher. Parts of the data presented here were derived from such sources as the National Science Foundation, the McGraw-Hill surveys, and others.

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PROBABLE LEVELS OF R&D EXPENDITURES IN 1983

SUMMARY OF FINDINGS

1. Battelle forecasts that the total U.S. expenditures for R&D will be \$83.6 billion during calendar year 1983. This is an increase of 8.2 percent over the \$77.3 billion that the National Science Foundation (NSF) estimates actually will be spent in 1982.
2. Costs of performing R&D are expected to rise 4.5 percent from 1982 to a 1983 index level of 211.14 (1972 = 100 percent), absorbing a considerable amount of the increased funding. However, this implies a *real* increase in expenditures of approximately 3.5 percent, reaching a new peak in total real funding of R&D (Figure 3).
3. Federal government funding in 1983 is expected to be about \$39.3 billion (47.0 percent of total), an increase of \$3.2 billion (8.8 percent) from 1982. Performance of R&D by the Federal government will represent \$10.8 billion (13 percent), an increase of \$0.8 billion (8.4 percent) over 1982 estimates.
4. Industrial funding in 1983 is expected to be approximately \$41.4 billion (49.6 percent of total) representing an increase of \$2.93 billion (7.6 percent) over that of 1982. Performance of R&D by industry is expected to rise to \$60.7 billion (72.5 percent of total), an increase of \$5.0 billion (8.9 percent) over 1982.
5. A feature of the 1982 R&D forecast and analysis that is continued this year involves estimates of Federal versus industry support for the R&D performed by each of several broad industrial sectors. Drawing upon historic trends, we have distributed the anticipated total performance by the industrial sector, first within each of 17 major industrial groups and then according to whether that performance is supported by Federal or industrial funds. These estimates are shown in Table 4.
6. In 1983, the Federal government is expected to support over three-fourth's of the aerospace industry's R&D activity, two-fifths of electrical machinery/communications and about one-third of rubber products. All other broad manufacturing industry classes are expected to be supported primarily by industry funds. These ratios range from 83 percent for machinery up to 100 percent for the textile, paper, and the food and beverage industries. Overall, 32.8 percent of industrial R&D will be Federally funded with the remainder (67.2 percent) funded by industry.
7. Academic and other nonprofit institutions taken together are expected to fund \$2.87 billion of R&D in 1983 (3.43 percent of total) and to perform \$12.1 billion (14.5 percent). Both of these figures represent small decreases in the percentage of support and performance over the 1982 NSF estimates. These figures also include the Federal support to Federally Funded Research and Development Centers which are managed by individual universities or consortia.
8. Within the nonprofit category, colleges and universities are expected to account for 61.3 percent of the 1983 funding and 80.1 percent of the R&D performance, an insignificant difference from the 1982 NSF estimates.
9. The costs of R&D performance have risen steadily in all four categories (Federal, industrial, colleges and universities, and other nonprofits), with the rate of increase being driven primarily by overall inflation, but also by the so-called "sophistication" factor.
10. The trends in real R&D effort (see Figure 3) are continuing the upward movement established over much of the past decade. Since 1973, real R&D effort has increased at a 9-year average rate of 3.30 percent, and the projections for 1983 suggest that the 10-year average rate will continue at about 3.33 percent. Battelle estimates that during the decade of the 1980s, real R&D activity will increase at an average annual rate of approximately 3 percent.
11. Significant factors that appear to be influencing trends in the support and performance of R&D include:
 - (a) Federal emphasis on defense and space programs will have a continued influence on total R&D support and the principal industrial performers; these emphases will be felt primarily in the aerospace and electronics and communications industries.
 - (b) Energy-related R&D programs will continue to experience decreased Federal support, with the exception of programs characterized as having very high risk or long-term payoff; even within these categories, there is little evidence that energy is perceived as a national problem requiring Federal R&D support.
 - (c) Although industrial support of R&D may be increased by tax credits already in place, the poor business and cash flow conditions of the recent past may tend to offset real increases in funding.

- (d) University self-funding of R&D is expected to begin to show real increases, partially as a result of expanded industrial "directed programmatic endowment" support of basic and applied research.

ANALYSIS AND FORECAST

Since research and development (R&D)* is Battelle's prime concern, it has an intense and abiding interest both in forecasting R&D expenditures and in assessing the cumulative results of R&D activities—technological, economic, and social. Accordingly, the Columbus Division has carried on a continuing inquiry into the forces affecting R&D activities and into their sources of support. Among the tangible outputs of this research have been a series of annual analyses and forecasts of R&D expenditures, of which the present report is the latest.

The content of this analysis and forecast of the R&D situation has evolved over the years in an attempt to supply information that Battelle considers useful to the R&D community, but was not being supplied by two well-known and respected series of reports: the National Science Foundation's *National Patterns of Science and Technology Resources* and the McGraw-Hill *Annual Survey of Business Plans for R&D*.

Earlier, the NSF *Patterns* were published during the first half of each year (usually in April) and included a forecast of that same full year's R&D expenditures, by source of funds and by performer. However, since the change to the fiscal year which now begins in October, *Patterns* contains both the preliminary data for the closing fiscal year and estimates for the two preceding years. Thus, the 1982 report (NSF-82-319) provides preliminary data on the 1980 activities and estimates performance for 1981 and 1982. The McGraw-Hill surveys (usually published at about the same time as *Patterns*) make forecasts—the 1982 Survey (published in May) made forecasts for 1982 and 1985—but are confined to the performance of the industrial sector and do not separate Federal from industrial funding. The Battelle report, usually published in December, has been intended to fill in a timely manner the niche that involves especially the coming year (in this case, 1983) and industrially funded R&D. Other relevant information, gleaned from many sources, also has been included.

*The National Science Foundation's definitions of R&D are given in the Technical Appendix to this report.

Beginning with the 1980 forecast, we also have included a forecast of industrial R&D expenditures by broad industry class, along with the estimated distribution of those funds between industrial and Federal sources. This added feature provides the background necessary to an understanding of the way in which Federal policy can affect industrial innovation, can spur industrial support of its own R&D efforts, and can enhance the longer-term international competitiveness of U.S. industry. Although related aspects of productivity, training and manpower needs, tax incentives, balance of payments, and other concerns are not predictable, we anticipate that continued analysis of this subject will help identify both the promises and the problems associated with industrial responses to future opportunities.

Historical Trends in R&D Funding and Performance

Although the NSF data series goes back to 1953, we begin our analysis with 1960. Even that year represents ancient history so far as the forces currently affecting R&D are concerned. The NSF data from 1960 through 1982 are shown in Table I.

In 1960, NSF surveys indicated that approximately 64.6 percent of all R&D supportive funds were provided by the Federal government; 33.4 percent were provided by industry; and 1 percent each came from the academic community and from other nonprofit organizations.

Between then and 1982, Federal funding rose to 66.5 percent in 1964, and has slowly declined to 46.7 percent.** Over that same time period, industrial funding declined to 31.2 percent in 1964 and has risen to 49.8 percent in 1982, with no significant change expected in 1983. The two nonprofit sectors have risen gradually, colleges and universities to 2.1 percent and other nonprofit to over 1.4 percent.

Generally, recent trends suggest a renewed increase in industry funding as a percent of total funding, with a corresponding decline in Federal sector contributions. The extent to which this behavior will continue will rest largely upon the posture assumed by the Administration, the industrial response to Federal initiatives, and the general state of the economy.

**Note that NSF data for 1980-1982 are "preliminary" or "estimated". However, comparisons among the series of *Patterns* reports reveals that adjustments are made on earlier years' figures, with such adjustments carrying back as far as 1970.

Although the Federal government has been the major source of R&D funds since 1953 (in recent years, however, its dominance has been eroded), industry is by far the major performer of R&D. Federal performance of R&D rose from 12.7 percent in 1960 to 16.1 percent in 1972 and has been fluctuating since that year, albeit with a generally decreasing percentage. Industrial performance reached a high point of 79 percent in 1957, and drifted steadily downward to a low of 68.6 percent in the early 1970's; more recent trends suggest a slow increase in the proportion of industrial performance, rising to about 72 percent. While the academic community's performance varied between 6 and 8 percent prior to 1960, there has been a slow but steady increase in the percentage of R&D performed in this sector, with recent proportions around 12 percent. For most of the 1960-80 period, other nonprofits, including

Battelle, have grown from 2 to about 3 percent of the total.

It should be noted that Federal funding supports research performed by all four sectors. Currently, just over one-fourth goes to support intramural R&D; almost half goes to industry; approximately one-fifth goes to colleges and universities; and the rest, slightly less than 4 percent, goes to other nonprofits. Industry absorbs almost all of its own funds, either intramurally or by contract with other industrial performers; its contracts and grants to colleges and universities slightly exceed those to other nonprofit institutions. Other nonprofits finance both themselves and the academic institutions about equally, while colleges and universities absorb all the funds that they originate.

In Table 1 we summarize the latest NSF time series on

**TABLE 1. SOURCES OF R&D FUNDS AND PERFORMERS OF R&D.
UNITED STATES, CALENDAR YEARS 1960-82**

(Millions of Current Dollars)

Year	Sources of Funds					Performance ^(a)			
	Total R&D	Federal Gov't	Industry	Colleges and Universities ^(b)	Other Nonprofit ^(c)	Federal Gov't	Industry	Colleges and Universities	Other Nonprofit ^(c)
1960	13,523	8,738	4,516	149	120	1,726	10,509	1,006	282
1961	14,316	9,250	4,757	165	144	1,874	10,908	1,173	361
1962	15,394	9,911	5,123	185	175	2,098	11,464	1,374	458
1963	17,059	11,204	5,456	207	192	2,279	12,630	1,611	539
1964	18,854	12,537	5,887	235	195	2,838	13,512	1,904	600
1965	20,044	13,012	6,548	267	217	3,093	14,185	2,103	663
1966	21,846	13,968	7,328	304	246	3,220	15,548	2,345	733
1967	23,146	14,395	8,142	345	264	3,396	16,385	2,594	771
1968	24,605	14,928	9,005	390	282	3,494	17,429	2,868	814
1969	25,631	14,895	10,010	420	306	3,503	18,308	2,950	870
1970	26,134	14,892	10,444	461	337	4,079	18,067	3,072	916
1971	26,676	14,964	10,822	529	361	4,228	18,320	3,216	912
1972	28,477	15,808	11,710	574	385	4,590	19,552	3,383	952
1973	30,718	16,399	13,293	613	413	4,762	21,249	3,701	1,006
1974	32,864	16,850	14,878	677	459	4,911	22,887	3,888	1,178
1975	35,213	18,109	15,820	749	535	5,354	24,187	4,396	1,276
1976	39,016	19,914	17,694	808	600	5,769	26,997	4,874	1,376
1977	42,982	21,727	19,696	887	672	6,105	29,928	5,454	1,495
1978	48,295	24,003	22,491	1,035	766	6,920	33,365	6,338	1,672
1979	54,994	26,935	26,028	1,194	837	7,564	38,147	7,289	1,994
^(d) 1980	62,222	29,576	30,400	1,313	933	7,929	43,879	8,284	2,130
^(e) 1981	69,790	32,910	34,385	1,490	1,005	9,000	49,600	8,950	2,240
^(e) 1982	77,285	36,125	38,500	1,600	1,060	10,000	55,700	9,300	2,285

Source: National Science Foundation, *National Patterns of Science & Technology Resources*, 1982 (NSF 82-319)

- (a) The R&D performance of Associated Federally Funded Research & Development Centers (some administered by industry, some by colleges and universities, and some by other nonprofit organizations) has been combined with that of the administering institutions.
- (b) As sources of funds, these include state and local government funding.
- (c) All other nonprofit institutions.
- (d) Preliminary figures provided by NSF.
- (e) Estimated by NSF.

the sources of R&D funding and on the volumes of R&D performance. During the interval since 1960 total R&D dollars (not adjusted for inflation) have more than quintupled. Federal funding has more than quadrupled and Federal performance has increased by a factor of 5.8. In terms of constant dollars, total R&D expenditures have increased by 69 percent during 1960-82, and Federal performance has increased by 40 percent (see Table 6). Using the same deflator for Federal funding that we used for total expenditures, real Federal funding increased by about 22 percent.

Also noteworthy is the high ratio of academic performance to academic funding. In the later years of this period, colleges and universities have provided about one-sixth of the total support of their own R&D activity, with the remainder coming primarily from the Federal government.

Beginning in 1968, there was a distinct change in the rate of growth in R&D, manifested by a leveling in current-dollar Federal funding. This phase of the recent past seems to have ended with 1971, when current-dollar expenditures resumed an accelerating growth trend more nearly like that before 1968. More recent trends suggest a continued growth of total real R&D support.

Continued Transition

As was pointed out in last year's forecast and analysis, U.S. R&D is in a period of significant transition. The forces governing this transition, insofar as the Reagan Administration is concerned, were stated in these terms: "Perhaps the overriding factors which characterize this Administration's posture are: (1) the major commitment toward expansion of defense capabilities; (2) a strong support of the private sector—both through taking positive actions and through relaxing negative requirements; (3) the belief that many areas of governance should be left to State and Local governments; and (4) an attempt to balance Federal budgets through the reduction or elimination of a broad range of programs.*"

Furthermore, Administration policy has strongly favored the reduction of support in those areas (especially energy) which (1) are no longer considered to represent national crises, or (2) are thought of as being more appropriate for the private sector. To these forces also should be added two factors that have become even more crucial with the passage of time than the policy directives of the

Administration: namely, worldwide economic depression and growing technological challenges from other countries.

There is practically nothing that we said last year that should not be repeated (with increased emphasis) this year. Nothing has happened either to reduce uncertainties or to add to optimism. Budgetary deficits are trending even higher than predicted, increasing pressures on the Congress to increase taxes (thereby reversing earlier Administration achievements) or to further reduce expenditures. The oft-heralded, but never grasped, economic turnaround is still in the indefinite future, increasing the possibility that industry may yet cut back on its support of R&D. In other words, if 1982 has been a year of uncertainty, 1983 promises to be even more of one. Nevertheless, even with this *caveat*, there are some things which can be foreseen and which provide a basis for our forecast.

Forecast for 1983

During calendar year 1983, Battelle expects the total current dollar volume of R&D activity to be higher than the level estimated by NSF to be achieved in 1982 (though not as great as expected by NSF for 1983). A comparison of Battelle's 1983 forecast with the last available NSF estimates for 1982 is shown in Table 2. The 1983 forecast is shown in its historical setting in Figure 1.

Referring to Table 2, we estimate total 1983 R&D volume to be \$83.600 billion, a 8.2 percent increase over the NSF estimates for 1982. It is expected that much of this increase will be absorbed by continued inflation (which we estimate to be 4.5 percent from 1982 to 1983 for R&D).

In connection with this forecast, there are three particular *caveats* that must be noted. First, the actual current-dollar total that will be realized in 1983 is very dependent upon inflation. The projection given here reflects, in part, the lowest adjusted R&D inflation rate in recent years.

Second, these projections cannot take into account the changes yet to be made as the Congress and the Administration finally compromise on the Federal budget for FY 1983. As of this writing, although the fiscal year has already begun, almost nothing is in final appropriation. Moreover, since this is a very significant off-year from the viewpoint of Congressional elections, the final shape of FY '83 may not be fully determined until after the new calendar year; and the philosophy of that determination must depend on the outcome of the elections.

*Page 4 of the 1982 Forecast and Analysis.

Third, as pointed out last year, the fact of continued depression in the business community may lead to reductions in industrial support of R&D. Observation of earlier business fluctuations indicates that business decision-makers generally tend to lag R&D commitments about 1 year behind cash flows. Thus, a disastrous 1982 may offset, or more than offset, first-time forces in favor of increased R&D.*

In using Table 2, the reader should keep clearly in mind all the distinctions made by the table headings. For instance, in the *column* headed "Industry", we see that the total amount of R&D expected to be performed by industry

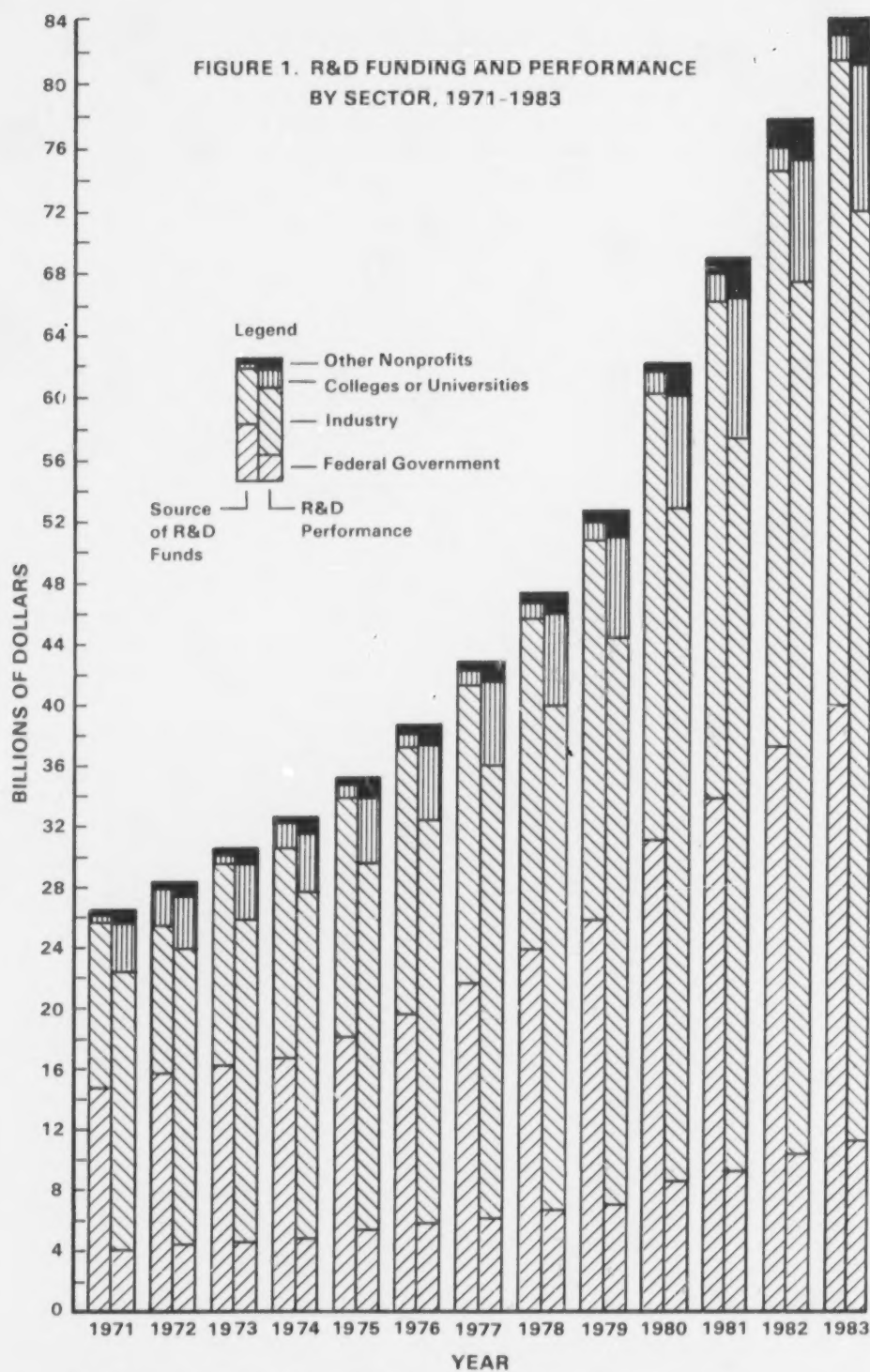
in 1983 will be \$60,664 million. Of this, \$19,913 million will be funded by Federal agencies, and \$40,751 million by industry. On the other hand, the *row* headed "Industry" indicates that industrial sources of funds are expected to support about \$41,434 million of R&D. Of this, \$40,751 million will be performed by industry, \$304 million by colleges and universities, and \$379 million by other non-profit organizations.

Continued inflation is expected to characterize 1983, although the rate, as experienced in R&D, appears to be declining. In addition, there are many intangibles—partly the increased feeling on the part of both Federal and industrial decision-makers that R&D is vital to long-term economic health—that favor continued increases in support. The NSF estimated that current dollar R&D activity rose by 10.7 percent from 1981 to 1982; we project a smaller increase, 8.2 percent, from 1982 to 1983. As will be shown

TABLE 2. ESTIMATED R&D EXPENDITURES BY SOURCE OF FUNDS AND BY PERFORMERS, U.S. CALENDAR YEARS 1982 AND 1983

(Millions of Current Dollars)

Source of Funds	Performer				Source Totals	
	Federal Government	Industry	Colleges and Universities	Other Nonprofit	Dollars	Percent of All Funds
1982 NSF Estimates						
Federal Government	10,000	17,800	6,950	1,375	36,125	46.74
Industry	—	37,900	275	325	38,500	49.82
Colleges & Universities	—	—	1,600	—	1,600	2.07
Other Nonprofit	—	—	475	585	1,060	1.37
Performer Dollars	10,000	55,700	9,300	2,285	77,285	
Totals Percent	12.94	72.07	12.03	2.96		100.00
1983 Battelle Forecast						
Federal Government	10,843	19,913	7,134	1,410	39,300	47.01
Industry	—	40,751	304	379	41,434	49.56
Colleges & Universities	—	—	1,757	—	1,757	2.10
Other Nonprofit	—	—	487	622	1,109	1.33
Performer Dollars	10,843	60,664	9,682	2,411	83,600	
Totals Percent	12.97	72.56	11.58	2.88		100.00
Percentage Increases Over 1982 Estimates						
Federal Government	8.43	11.87	2.65	2.55	8.79	
Industry	—	7.52	10.55	16.62	7.62	
Colleges & Universities	—	—	9.81	—	9.81	
Other Nonprofit	—	—	2.53	6.33	4.62	
Performer Totals	8.43	8.91	4.11	5.51	8.17	



See Tables 1 and 2. 1971-1982 estimates by NSF; 1983 projected by Battelle's Columbus Division.

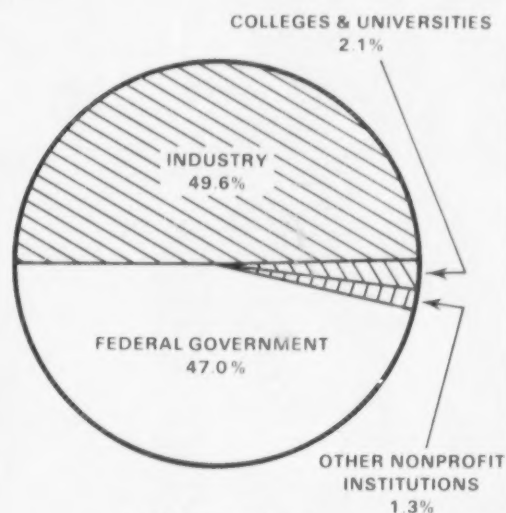
in connection with the Cost of R&D Index, not all of this increase is expected to be absorbed by inflation.

With respect to the *composition* of R&D activity, the expected pattern continues to be one of year-to-year stability or very slow change, with defense, Federal regulations, and science- and technology-based problems still pro-

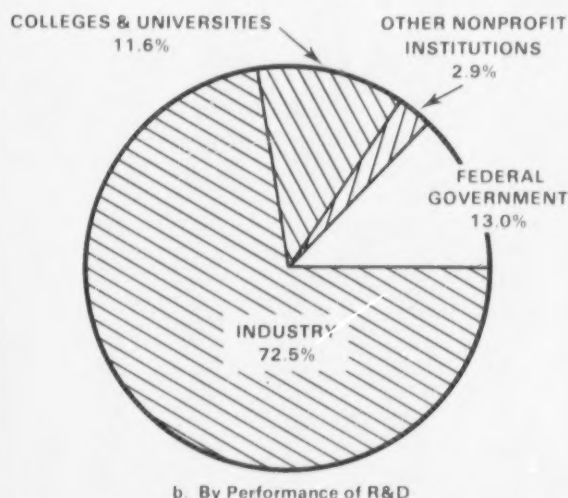
viding the major impetus for change. The proportionate composition of both funding and performance will change very little. The Federal government will account for 47.0 percent of the total funding, as against 49.6 percent for industry. Industry will account for almost three-fourths of total performance. These two distributions for 1983 are summarized in Figure 2.

FIGURE 2. R&D EXPENDITURES IN THE U.S., CALENDAR YEAR 1983

The total forecast by Battelle's Columbus Division is \$83.6 billion. Distribution shown here is by source and performance.



a. By Source of Funds



b. By Performance of R&D

Source: Battelle's Columbus Division

The Role of Federal Agencies

Since Federal funding was historically the major source of R&D support (although it has been increasingly outdistanced by industrial support since 1980), the forces likely to affect Federal R&D budgets in Fiscal Years 1983 and 1984 are important in the present forecast. The Budget for Fiscal Year 1983, which began on October 1, 1982, bears little of the influence of the earlier Carter Administration. It exhibits major departures from prior trends and sets the stage for what may be significant changes in subsequent years.

It is now apparent that increases in defense spending—in terms of both hardware and research—will be spurred by the Administration's commitment to new weapons systems. Regardless of the outcome of the off-year elections and the final appropriation bills, this probably will dominate the Federal R&D budget. Furthermore, budget plans through 1987—while certainly subject to modification in the future—set a direction which suggests continued emphasis in this area.

Battelle projects \$39.3 billion as the most likely level of Federal funding in calendar year 1983. This figure is based upon: (a) recent trends in Federal budgeting, as reflected in NSF data series on R&D funding; (b) the relationship between Federal funding and Federal obligations; (c) the fact that three calendar quarters' funding will be determined by the FY 1983 appropriation; and (d) a strengthening of selected mission agency activities. We note that this estimate is slightly lower than that proposed in the FY '83 budget, the discrepancy expected as a result of final authorizations

The R&D-Minded Agencies

The big-money agencies in terms of total 1983 R&D funding will include the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the Department of Health and Human Services (HHS). Among the smaller agencies, the important suppliers of funds for

extramural R&D are the NSF, the Department of Agriculture (DOA), the Environmental Protection Agency (EPA), the Department of the Interior (DOI), the Department of Commerce (DOC), and the Department of Transportation (DOT). Estimated shares for the conduct of R&D in the early proposed budgets for FY 1983 and comparative estimates of the FY 1982 plans are:

	1982 Estimated Obligations	1983 Planned Obligations
DOD	52.2 percent	56.6 percent
NASA	14.9	14.9
DOE	13.1	10.4
HHS	9.9	9.3
NSF	2.4	2.4
DOA	2.1	1.9
DOT	0.8	0.9
DOC	0.8	0.6
DOI	0.9	0.8
EPA	0.7	0.5

It is obvious from this listing that DOD continues to dominate the Federal scene, accounting single-handedly for over one-half of the R&D budget. The Big Four (DOD, NASA, DOE, and HHS) account for 91.2 percent of anticipated Federal R&D expenditures. The next six largest R&D-supporting agencies account for only 7.1 percent, and all others combined account for less than 2 percent.

These percentage distributions reflect the first impacts of the Reagan Administration. The 1983 structure is still subject to modification by the Congress.

Functional Categories

Although some of the important R&D agencies are primarily devoted to a single function, many are multifunctional. The NSF utilizes a master list of 16 functional categories, of which the most important have the following shares of estimated 1982 and 1983 obligations:

	1982	1983
National defense	56.9 percent	61.2 percent
Space research & technology	13.9	14.0
Health	10.0	9.3
Energy	7.5	4.7
General science	3.6	3.5
Environment & natural resources	2.5	1.9
Transportation	1.9	1.9
Agriculture	1.8	1.7

The remaining functional fields, each receiving less than .5 percent of the total R&D budget, are: education, training, employment and social services; community and regional development; international affairs; veterans' benefits and services; commerce and housing credit; income security; administration of justice; and general government. Altogether, these smaller fields account for only 1.8 percent of the total.

Attention is called to the fact that, although at the time of writing the 1982 forecast it appeared that only defense appropriations were expected to increase over 1981, in fact several other functional budgets also increased, particularly space and general science. At this time, even more functional increases are expected (e.g., health). Of the major fields, only energy R&D is expected to decline from 1981 to 1982 to 1983.

The significant increase in defense spending primarily is directed toward the acquisition of major weapons systems and the R&D that will be necessary to support them. The emphasis on space-related R&D also is expected to continue, although probably at a lower rate of effort. The continued success of the Space Shuttle program and the potential use of the shuttle as an instrument for more economical insertion and repair of satellites is seen as justifying continued support of the program for both civilian and defense purposes. However, purely scientific NASA activity may well decline.

From 1969-70 to 1973-74, year-to-year changes in R&D budgets favored civilian programs over defense/space. Beginning with 1974-75, emphasis has tended to shift back toward defense and space, especially the former. Throughout the 1970's, the funding of energy-related R&D generally grew by larger increments than that of space or of most other civilian programs. It is generally expected that Federally-supported energy-related research and demonstration programs will decline, even though efforts to dismantle the Department of Energy may be abandoned. Although some existing DOE programs may be transferred to other agencies, and those which involve short-term and/or low-risk R&D will probably have to be financed by private industry, there are continuing pressures to maintain the DOE entity, even with a restructuring of the Department's R&D facilities.

Factors Affecting Future Federal Support

There appears to be a continuing effort on the part of the Federal government to increase its funding of R&D,

in terms of both support to basic national needs and the broadening of the technological base on which future growth is predicated. National security, reflected in the DOD budget, is seen as a principal driving force in furthering R&D spending. Economic growth, founded upon both basic and applied research, is expected to remain as an objective which requires direct and indirect Federal support, although greater emphasis will be directed toward the latter.

The continuing emphasis on energy, and the associated problems of balance of payments and insecure resources, will result in increased efforts on the research, development, demonstration, evaluation, and diffusion of new energy technologies. These efforts will be directed toward both the supply and the consumption sides of the energy equation, but with decreasing Federal involvement.

Energy research is expected to continue regardless of the Department of Energy's future, although much energy R&D will be left to the private sector. While reorganization of DOE may disrupt some of the day-to-day operations, it would not be expected to affect the commitment to, or performance of, that energy research which is generally deemed to be in the long-range interests of the nation. Here, again, indirect Federal support will play the more important role.

In addition, it is anticipated that R&D moneys will continue to support the biological science areas. However, less emphasis will be placed on "soft" science areas, except those environmental, ecological, and socioeconomic impact investigations presently mandated by law.

Previous reports in this series addressed the concern that Federal funds might shift from extramural support to internal Federal laboratory programs. Last year's analysis suggested that this would not be the case, and the most recent NSF data and Battelle's 1983 projections confirm this conclusion. The shares of Federal R&D funding which have been and probably will be performed in Federal laboratories are:

1977	28.1 percent
1978	28.8 percent
1979	28.1 percent
1980	26.8 percent
1981	27.3 percent
1982	27.7 percent
1983	27.6 percent

Greater effort is now being made to "sell" the capabilities of the Federal laboratories as resources available to

both the Federal and non-Federal markets. There are, however, conflicts among the various factors that may influence the ultimate outcome of this effort. While Federal regulations permit considerable involvement by Federal laboratories in response to external needs, there also are several real and perceived restrictions. Whether the Federal laboratories will be more heavily involved in R&D performance as a result of actions taken in response to PL 96-480, is yet to be seen. For the near future, however, we see no reversal of the above-noted trend.

Last year's analysis pointed to a potential shift of Federal funding from colleges and universities to other non-profit performers. As of this writing, the shift is not continuing and, to the degree that the Administration's attempts to redirect R&D funding are frustrated by Congress, it may already have ended.

The Role of Industry

NSF data indicate that industrial support has been greater than Federal support since 1980 and Battelle projects industrial support of R&D to be greater than that from the government in 1983. As has been the case in all previous years, industry will be by far the predominant R&D performer.

During 1982, the NSF has estimated that industry will provide 49.8 percent of total funding and perform 72.1 percent of all R&D work (see Table 2). Battelle's forecast for 1983 changes these shares almost imperceptibly to 49.6 and 72.6 percent, respectively.

The NSF data base indicates that industry also has been the fastest growing sector. Table 3 compares sectoral growth rates for the nine-year interval 1973-82. In connection with this table, attention is called to two relationships. First, every sector tends to grow somewhat slower as a performer than as a source of funds.* And second, in the case of the government, the fact that this differential exists also indicates a lack of support for the thesis that Federally funded R&D is being transferred to Federal laboratories.

Battelle projects considerable differences among the 1982-83 sectoral growth rates. Total R&D expenditures are expected to grow by 8.2 percent; industrial funding and performance are expected to increase by 7.6 and 8.9 percent, respectively. This represents the second lowest growth

*Although this appears to be a mathematical anomaly, it results from substantial differences in the two weighting patterns.

rate among the funding sectors, and the highest growth rate among the performing sectors.

TABLE 3. SECTORAL GROWTH RATES IN FUNDING AND PERFORMING R&D, 1973-82

Sector	1973 = 100.0%	
	Source	Performer
Total United States	251.6	251.6
Federal Government	220.3	210.0
Industry	289.6	262.1
Colleges & Universities	261.0	251.3
Other Nonprofit	256.7	227.1

Source: Derived from Table 1.

Industrial funding is expected to rise from an NSF estimated level of \$38,500 million in 1982 to \$41,434 million in 1983. Industrial performance will rise from \$55,700 million to \$60,664 million. As will be seen later, this total performance implies a definite increase in *real* industrial R&D activity (4.5 percent).

Industrial research, as it applies to the accomplishment of industrial and governmental objectives, is both a means to an end and an end in itself. While the continuing profit motive in a competitive marketplace spurs R&D for individual industry's benefit, so also does the industrial system provide a mechanism for the execution of programs of high national priority. In view of: (a) the continuing emphasis on innovation and "reindustrialization", and (b) recent tax incentives for industrial R&D, Battelle's 1983 forecast continues a new area of analysis, namely, the comparative Federal and industrial funding of R&D in major groups of industries.

Using data derived both from NSF sources and from interpolation or extrapolation of the McGraw-Hill surveys, we have estimated the degrees to which industrial and Federal funds will support industry R&D (see Table 4). As yet, there is no way of determining the effect of Federal initiatives on these distributions.

The tax incentives mentioned above could contribute to increases in industrial support of R&D. However, it must be noted that these incentives are applicable to *incremental increases* in R&D support; that they are confined to the so-called "hard" sciences; and that industrial R&D support levels are closely correlated with profits—business

slowdowns in one year being reflected in decreased R&D efforts in subsequent years.

With reference to Tables 2 and 4, the performance of R&D by industry will be financed either by the Federal government or by industry itself. Industrially funded work will mostly be done by industry although a very small amount (less than 2 percent) will be done extramurally. The nonmanufacturing industries do relatively little R&D and, as noted in Table 4, support for this activity is divided almost equally between Federal and industrial funding. In contrast, R&D is much more heavily self-funded by (and in) the manufacturing industries where, on the average, about 32 percent of the total performance is supported by Federal funds.

The electrical machinery and communication industry, rated second in R&D performance last year, is projected to lead in 1983 with almost \$13 billion, of which 41 percent is Federally funded. In second place, the aerospace industry (last year's leader) is projected to do almost \$12 billion of R&D, with almost 80 percent of its funds from Federal sources. Further appropriations for the B-1 and the Stealth bombers and/or the MX missile system will affect both these top-ranked industries.

Aside from aerospace, where Federal funds account for slightly under 80 percent of all R&D moneys, there are no industry groups in which more than half of the R&D performance is expected to be supported by Federal grants and contracts. In addition to electrical machinery and communication (41 percent Federal) and rubber products (34.5 percent), no other industries receive as much as 17 percent of their funding from Federal sources.

Finally, we call attention to the fact that the total industry fundings shown in the third column of Table 4 make no distinction between R&D performed in-house or that contracted out to academia, to nonprofit organizations, or to other industrial firms.

Factors Affecting Future Industrial Support

When taken as an isolated factor, the tax incentives noted earlier are not expected to have a significant impact on industrial research. However, when coupled with other incentives, the environment for increased industrial research may be enhanced. For example, continued deregulation and the emphasis on long-range reindustrialization can promote expansion of the industrial research enterprise.

More important, however, is the growing sense on the part of business that R&D activities are directly linked to productivity, international competitiveness, and profitability.*

In addition, advances in applied sciences—including genetic engineering, robotics, and communications—are seen to have potentially large impacts on both industrial processes and the business of doing business. Furthermore, the rebuilding of industrial plants and the incorporation of new technologies will require expanded R&D efforts directed toward the adaptation of available knowledge.

The Role of Academic and Other Nonprofit Institutions

Nonprofit institutions—colleges, universities, and other types—both fund their own research and conduct

*See, for example, the recent publication by Clark and Griliches, *Productivity Growth and R and D at the Business Level: Results from the PIMS Data Base* (NBER Working Paper No. 916).

research funded by Federal agencies and/or industrial firms. It is generally conceded that a significant portion of all basic research is conducted in this sector, as well as some of the longer maturing applied research.

In 1960, the academic and other nonprofit institutions financed from their own resources (including endowments and direct state and local funds) approximately 2 percent of all R&D (see Table 1), while actually performing over 9 percent of the total. For 1983, Battelle forecasts (see Table 2) that these same nonprofits will provide 3.4 percent of all funding and will perform 14.5 percent of the total.

These percentages are consistent with the corresponding ratios for the 1982 NSF estimates, with academic and nonprofit performance decreasing slightly.

Reference to Table 3 indicates that the two nonprofit sectors have been growing faster during 1973-82 than total R&D, both in the generation of funds and in the performance of R&D.

TABLE 4. ESTIMATED SOURCES OF FUNDS FOR R&D BY BROAD INDUSTRIAL CLASSES, 1983

(Millions of Current Dollars)

Industry Class	Federal Funds	Industry Funds	Total Funds	% Federal
Electrical Machinery and Communications	\$ 5,266	\$ 7,621	\$12,887	40.9%
Aerospace	9,429	2,400	11,829	79.7
Machinery	1,508	7,546	9,054	16.7
Autos, Truck & Parts, & Other				
Transportation Equipment	1,037	6,153	7,190	14.4
Chemicals	682	6,150	6,832	10.0
Professional & Scientific Instruments	221	3,213	3,434	6.4
Petroleum Products	310	2,161	2,471	12.5
Fabricated Metals & Ordnance	76	711	787	9.7
Rubber Products	269	510	779	34.5
Food & Beverage	0	723	723	0.0
Paper	0	669	669	0.0
Stone, Clay, & Glass	20	511	531	3.8
Nonferrous Metals	40	456	496	8.1
Iron & Steel	6	347	353	1.7
Textile Mill Products & Apparel	0	138	138	0.0
Other Manufacturing	22	445	467	4.7
Total Manufacturing	18,886	39,754	58,640	32.2
Nonmanufacturing	1,027	997	2,024	50.7
TOTAL	19,913	40,751	60,664	32.8

The growth in nonprofit R&D performance has been accompanied by minor shifting within the nonprofit sector. In 1960, the academic community (universities and colleges) accounted for 55.4 percent of total nonprofit funding and performed 78.1 percent of the nonprofit total. For 1983, Battelle forecasts 61.2 percent and 80.1 percent, respectively.

Attention is called to the part played in these developments by the nonacademic nonprofit organizations. There are two distinct groups of these "other" nonprofit organizations, the *foundations* which exist primarily for charitable purposes and the *nonprofit research centers* which may or may not perform under contract. The first group funds a great deal of research, primarily through the mechanism of grants; and these grants go both to members of the academic community and to other nonprofit centers. The second group acts in three ways: a member may perform as a foundation; it may fund its own research performance; and/or it may perform under contracts (with government, industry, or other nonprofits).

From 1965 to 1980 other nonprofit performance has fluctuated slightly between 3.3 and 3.7 percent of total R&D. Since then, this sector has declined to less than 3 percent. For 1983, Battelle estimates that the other nonprofit sector will comprise 2.88 percent of total R&D performance. Furthermore, we estimate that 43.9 percent of other nonprofit funding will go to colleges and universities, with the remaining 56.1 percent being spent by the other nonprofit sector itself. This division of support is slightly below that estimated by NSF for calendar year 1982.

Finally at this point, attention is called to the variety of forms taken by industrial support for academic R&D. In addition to contracts or grants to support research on industrial problems (this is the "industry funding of colleges and universities" shown in Table 2) there is a new form of support, not reported by the NSF, that must be noted. These industry/university arrangements take a form that more nearly resembles a "directed endowment" rather than either a specific research contract or a general gift. The large multiyear programmatic grants are then accounted for in terms of college and university self-funding.

Although major endowments of universities or individual departments may accomplish objectives that are important both to academia and to industry, not all such partnerships have been completely welcomed. On the positive side, these major programs may foster advanced university research and industrial access to faculty and

graduate students. Furthermore, they provide a mechanism for promoting further graduate research and education—countering a trend that has been disturbing to both the universities and industry.

On the other hand, there has been some reluctance toward the development and concentration of university research programs in areas closely tied to potential commercial ventures. The academic community may be willing to develop patents and possible commercial spinoff industry, but there is certainly less enthusiasm for creating situations in which external forces might dictate department policy. Industrial reluctance for these arrangements derives from the difficulty of maintaining proprietary claims and confidentiality with respect to the findings of industrially sponsored research.

The Cost of R&D Inputs

From an economic point of view, inflation can be defined as a general rise in the prices of goods and services that is not offset by corresponding increases in quality. If the prices of everything tend to rise together, slowly, and in the same proportions—and if individual incomes also rise in those same proportions—the relations between money and goods/services change, but in a fashion which is detrimental mainly to the holders of such fixed-dollar obligations as life insurance. On the other hand, when the prices of things bought with income rise faster than the incomes, structural imbalances occur which may be quite painful to particular sectors of the economy.

Goods Versus Services

Most considerations of prices tend to take place within the context of goods' prices, i.e., the prices of tangible things. The very tangibility of goods makes it possible both to measure the quantity of their output and to estimate, within reasonable limits, changes in their quality. Thus, with respect to goods, there usually is agreement as to whether or not costs are rising faster than output, or prices faster than quality—that is to say, we tend to have general agreement that inflation is or is not occurring in the goods-related economy.

Services, on the other hand, are intangible. Therefore we usually have greater difficulty achieving agreement that, in terms of any meaningful measure, the quantity or quality of service output is rising or falling. As a result, our only measure of many types of service output is the total amount of money that we pay for them—and that is a function of price and quantity, with no account taken of quality.

R&D, by definition a part of the "knowledge industry", is primarily a service activity, despite the fact that much of it ultimately becomes embodied in products. For this reason, we have no agreement as to what can be termed a "unit" of R&D output; and we, therefore, cannot ascertain whether or not the "price" of R&D output is rising or falling. We can price R&D inputs, however, and for that reason most discussions of the cost of R&D tend to be couched in those terms. Battelle has not yet given up hope of achieving a measure of R&D output, and from time to time has undertaken investigations which may lead to the quantification of at least some kinds of R&D output. Nevertheless, such a measure is not now available and the discussion which follows must be in terms of input costs.

The "Cost of R&D Input" Index

In the absence of a measure of R&D output costs, many organizations, including the NSF, use the GNP deflator (from the national income and product accounts) as an indicator of changes in R&D costs. This index responds to the costs of both goods and services. R&D costs are made up primarily of service costs, however, for which reason Battelle researchers feel that the GNP deflators probably have misstated recent rates of inflation with respect to R&D.

Several attempts have been made in the recent past to determine the input mixes of typical R&D activities and to price each input, thereby generating standard weighted price indexes for R&D. To date, this approach has not been very productive, although such efforts continue and may eventually achieve success.

A pioneering effort at more directly measuring trends and fluctuations in the cost of R&D was made by Helen Milton* beginning in 1966. Using information supplied by representative R&D performers Milton compiled data on the total dollar cost of R&D per technical (professional) man-year.** Her series of cost indexes ended with 1970, using 1950 as the base year. Between 1970 and 1979 Battelle extended the Milton Index series by means of annual estimates. Finally a new series of R&D cost indexes was introduced in the 1980 Battelle Forecast and Analysis. This new series, while conceptually similar to the Milton Series, is based upon a different body of data and does not show precisely the same year-to-year changes as the Milton Series and our earlier extensions thereof.

*See Helen S. Milton—"Cost of Research Index, 1920-1970". *Operations Research*, 20, 1-18 (1972).

**Milton said on p. 1, "The 'technical man' is the professional scientist or engineer, plus his support".

The Battelle Cost of Research Index, displayed in Table 5, is based upon two series regularly published by the NSF: (a) the R&D performance figures, by Sectors, that have already been discussed in connection with the Source/Performer Matrix (Table 2); and (b) estimates of the full-time equivalent numbers of R&D scientists and engineers employed by each performing sector. The ratio of costs to scientists/engineers for each sector provides the basis for the sectoral subseries, which are then weighted and combined into the all-sector average.***

As derived from Table 5, Battelle's best estimates of recent increases in the total index are 8.5 percent for 1979-80, 7.8 percent for 1980-81, and 6.5 percent for 1981-82. We expect the cost of R&D to increase by about 4.5 percent between the estimated 1982 level (202.11) and the forecast level for 1983 (211.14) with the estimates stated in terms of the 1972 base.

Sector Comparisons of R&D Costs

During the interval 1972-83 costs of all R&D, as an average, are estimated to have risen by 111.14 percent. Increases in the individual performing sectors are expected to be: Federal government, 122.74 percent; industry 108.12 percent; colleges and universities, 122.25 percent; and other nonprofit, 97.18 percent. As noted, the 1982-83 cost increase for all R&D is estimated to be 4.5 percent. By sectors, the increases are estimated as Federal, 8.0 percent; industry, 4.2 percent; colleges and universities, 2.2 percent; and other nonprofits, 4.8 percent.

Trends in Real R&D Effort, by Sectors

If we take total expenditures and sector performance figures from Tables 1 and 2 and deflate them to constant 1972 dollars with the corresponding index numbers from Table 5, we can make parallel comparisons for each of the four performing sectors. These are shown in Table 6 and graphed in Figures 3 and 4.

In current (undeflated) dollars, total U.S. R&D expenditures have risen in every year of the period, even though the rate of increase fell sharply between 1969 and 1971. But

***As noted, in the text, the Battelle Cost of Research Index is derived from both NSF data and our own projections. Variations in the historical cost index, as reported in these Forecasts, are generally attributable to changes in the NSF data, which are continuously adjusted. Note, for example, that the *Patterns* report for 1982 contains adjustments in data dating back to 1970.

the deflated (real effort) series before 1978 reached its peak in 1969, declined between 1969 and 1973, and moved generally sideways until 1977, when it exceeded \$30 billion for the first time in 7 years. We expect real R&D effort in 1983 to increase by 3.5 percent over 1982 and to reach a level that is 29.5 percent above its 1969 peak.

When we shift our attention to the performing sectors, we find that the recent upward drift of real R&D activity results from the behavior of the private sectors. The downturn in real expenditures that began after 1968-69 is clearly reflected by every sector. However, deviations in sector behavior emerged later, especially since about 1975. In government, the real performance series has recovered only slowly from its 1974 minimum and has not yet equalled its 1969 peak.

In the private sectors, industry reached its real low in 1972 and has since risen by 49 percent to its highest

recorded value. The academic community reached its low in 1973. Since then, its real performance has risen by 34 percent and now stands well above the 1968 value. Other nonprofit institutions' real performance declined from 1968 through 1970. Since that time it has risen by 32 percent to a level 26 percent above the 1968 peak.

Finally, we return to the data of Table 6 and curves of Figure 4 and note the relatively stagnant behavior of Federal support for R&D. To be sure, there has been a continuing commitment to advancing research and technology (although, in constant dollar terms, less than a one percent growth per year over the past decade), with the vast majority of effort being directed toward defense, space, and health issues. However, the real growth in R&D—and the economic development and expansion which result therefrom—has come from the applied R&D supported by private industry.

TABLE 5. BATTELLE COST OF RESEARCH INDEX* BY PERFORMING SECTORS, CALENDAR YEARS 1960-83 (1972 = 100.00)

Year	Total U.S.	Performing Sectors			
		Federal Government	Industry	Colleges and Universities	Other Nonprofits
1960	59.79	50.03	62.97	48.15	72.56
1961	60.68	51.45	63.28	52.65	74.47
1962	62.97	54.71	64.91	57.96	78.86
1963	66.50	56.59	68.49	64.21	79.63
1964	71.09	67.38	71.53	71.80	78.07
1965	72.59	70.22	73.70	75.37	76.29
1966	76.65	69.94	78.00	77.44	78.43
1967	78.13	71.01	79.47	79.63	79.53
1968	80.31	71.25	81.81	82.87	83.96
1969	83.85	71.75	85.94	85.35	93.97
1970	88.76	85.16	88.87	90.46	98.94
1971	93.04	90.15	93.15	95.19	97.59
1972	100.00	100.00	100.00	100.00	100.00
1973	107.63	106.05	107.20	113.76	103.30
1974	114.14	109.72	114.57	116.27	118.31
1975	120.57	118.49	120.34	123.17	125.40
1976	130.35	126.47	130.80	132.24	131.84
1977	137.64	132.39	137.77	142.62	139.73
1978	148.18	146.44	146.09	161.71	150.74
1979	162.16	159.11	158.77	183.34	172.30
1980	175.97	166.04	173.26	203.06	180.65
1981	189.75	188.47	186.26	214.39	186.52
1982	202.11	206.33	199.64	217.36	188.22
1983	211.14	222.74	208.12	222.25	197.18

*Costs of performing R&D per scientist/engineer (full time equivalence).

Source: Estimated by Battelle from NSF and Battelle data.

Over the past few years, Federal support has tended to shift toward more "development" and less basic and applied "research". If such trends continue, the long-range consequences may pose significant problems in terms of the science base upon which economic vitality grows. Such problems may, in part, be mitigated by a continuation of the recent resurgence of basic research support by industry (the "directed endowments" referred to earlier). However, the volatility of those indicators (sales, profits, cash flow) which influence industrial R&D budgets precludes a

stability for long-term planning.

Thus, the Federal government, in any attempt to maintain the vitality of our technology-based and technology-influenced economy, should reexamine its policies relative to (a) the support of R&D, (b) the roles of the private and public sectors, (c) the factors which enhance or impede the progress of science and technology, and (d) the commitment to science education at all levels.

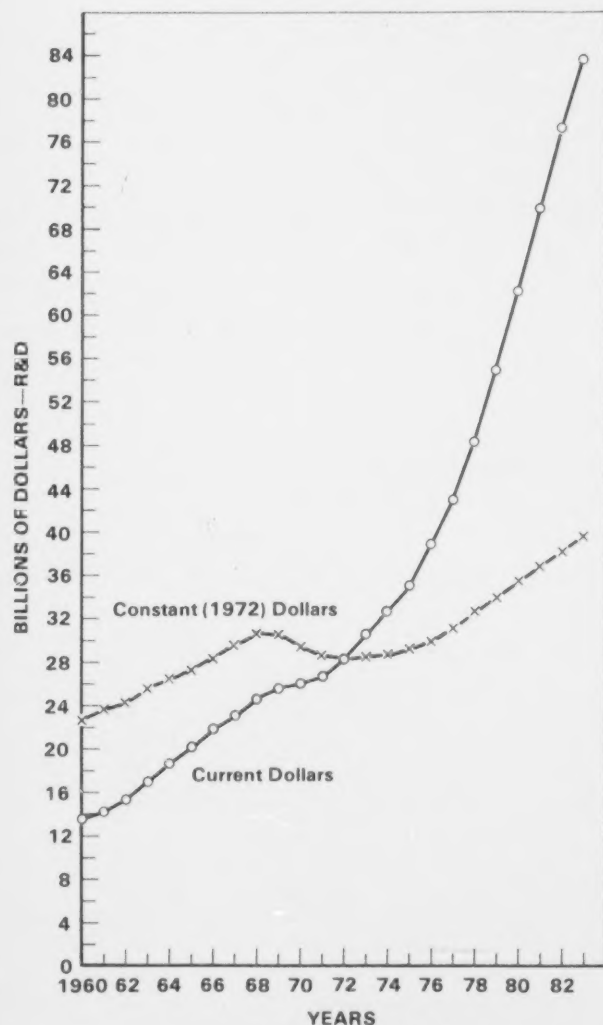


FIGURE 3. TOTAL R&D EXPENDITURES, 1960-83, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1972 = 100%)

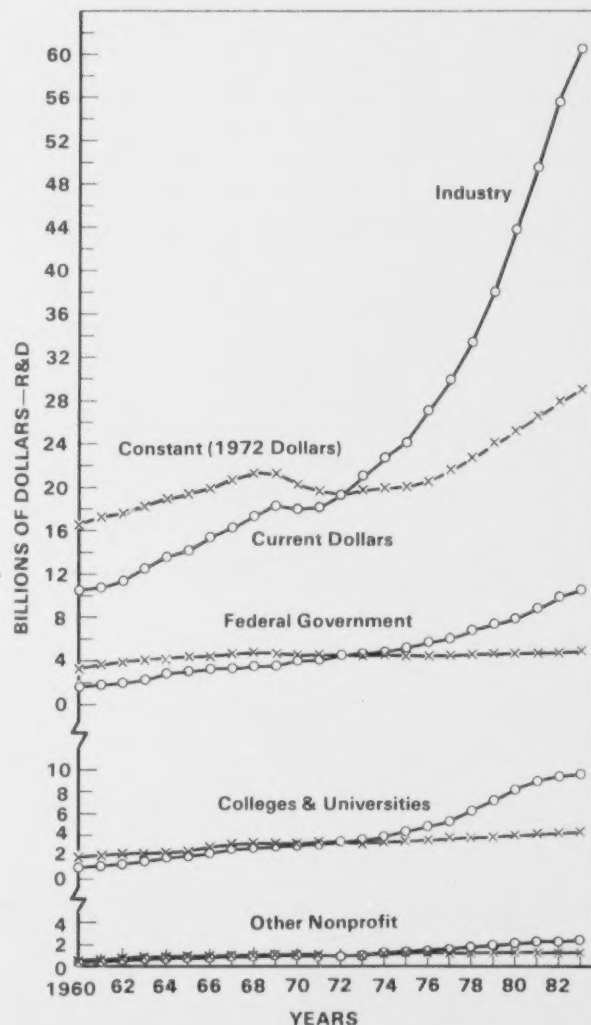


FIGURE 4. R&D EXPENDITURES BY SECTORS, 1960-83, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1972 = 100%)

TABLE 6. CURRENT AND CONSTANT DOLLAR (1972 = 100) R&D EXPENDITURES IN THE U.S., 1960-1983, BY PERFORMERS

(All Amounts in Millions of Dollars)

Year	Total U.S.		Federal Government		Industry		Colleges and Universities		Other Nonprofit	
	Current Dollars	Constant Dollars	Current Dollars	Constant Dollars	Current Dollars	Constant Dollars	Current Dollars	Constant Dollars	Current Dollars	Constant Dollars
1960	13,523	22,619	1,726	3,450	10,509	18,690	1,006	2,090	282	389
1961	14,316	23,592	1,874	3,642	10,908	17,237	1,173	2,228	361	485
1962	15,394	24,448	2,098	3,834	11,464	17,662	1,374	2,371	458	581
1963	17,059	25,654	2,279	4,027	12,630	18,441	1,611	2,509	539	677
1964	18,854	26,522	2,838	4,212	13,512	18,889	1,904	2,652	600	769
1965	20,044	27,312	3,093	4,405	14,185	19,248	2,103	2,790	663	869
1966	21,846	28,500	3,220	4,604	15,548	19,933	2,345	3,028	733	935
1967	23,146	29,627	3,396	4,782	16,385	20,618	2,594	3,258	771	969
1968	24,605	30,637	3,494	4,904	17,429	21,303	2,868	3,461	814	969
1969	25,631	30,568	3,503	4,882	18,308	21,303	2,950	3,457	870	926
1970	26,134	29,443	4,079	4,790	18,067	20,331	3,072	3,396	916	926
1971	26,676	28,672	4,228	4,690	18,320	19,668	3,216	3,379	912	935
1972	28,477	28,477	4,590	4,590	19,552	19,552	3,383	3,383	952	952
1973	30,718	28,540	4,762	4,490	21,249	19,823	3,701	3,253	1,006	974
1974	32,864	28,793	4,911	4,476	22,887	19,977	3,888	3,344	1,178	996
1975	35,213	29,205	5,354	4,519	24,187	20,099	4,396	3,569	1,276	1,018
1976	39,016	29,931	5,769	4,561	26,997	20,640	4,874	3,686	1,376	1,044
1977	42,982	31,228	6,105	4,611	29,928	21,723	5,454	3,824	1,495	1,070
1978	48,295	32,592	6,920	4,725	33,365	22,839	6,338	3,919	1,672	1,109
1979	54,994	33,914	7,564	4,754	38,147	24,027	7,289	3,976	1,994	1,157
1980	62,222	35,359	7,929	4,775	43,879	25,325	8,284	4,080	2,130	1,179
1981	69,790	36,780	9,000	4,775	49,600	26,629	8,950	4,175	2,240	1,201
1982	77,285	38,240	10,000	4,847	55,700	27,900	9,300	4,279	2,285	1,214
1983	83,600	39,595	10,843	4,868	60,664	29,148	9,682	4,356	2,411	1,223

Source: Current dollar figures from Tables 1 and 2, deflated in terms of Battelle R&D Cost Index of Table 5.

TECHNICAL APPENDIX

NSF DEFINITIONS OF RESEARCH AND DEVELOPMENT

Many activities, from one viewpoint or another, may be termed "Research and Development". The National Science Foundation (NSF) has, since its inception, been concerned with both the definition and the measurement of R&D. We probably can do no better than again quote the most recent definitions that the NSF has evolved. By these definitions, we can say:

"Research and development . . . consist of basic and applied research in the sciences (including medical sciences) and in engineering and activities in development . . .

"Research, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

"Basic research. For three of the sectors—federal government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with . . . a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to

indicate that basic research projects represent . . . original investigations for the advancement of scientific knowledge . . . which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

"Applied Research. The following is the core definition in the NSF questionnaire sent to the universities and colleges: 'Applied research is directed toward practical application of knowledge'. Here again, the definition for the industry survey takes account of the characteristics of industrial organizations it covers: . . . research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes'. By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

*"Development. The NSF survey concept of development may be summarized as: . . . the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes".**

*National Science Foundation, *National Patterns of R&D Resources*, 1953-78/79. NSF 78-313, p. 25.

ABOUT BATTELLE-COLUMBUS

Battelle's Columbus Division is the original contract research center of Battelle Memorial Institute, an internationally recognized nonprofit scientific research and development organization with laboratories and offices throughout the world.

Research at Battelle-Columbus encompasses virtually all facets of science and its application, including fundamental research and education. Studies are funded by small and large industrial firms; by municipal, regional, state, and Federal government agencies; and by associations and private groups in the United States and abroad. Research ranges from performing short-term, modest, problem-solving investigations to conducting and managing long-term, multidisciplinary, multimillion-dollar programs.

In conducting research, Battelle provides the sponsor with the physical facilities, equipment, and personnel on a contract basis. More than 2,000 studies in diverse fields are pursued in a typical year. Among the major research areas are energy, environmental quality, resource management, technical economics, social and behavioral sciences, health sciences, engineering and manufacturing technology, materials sciences, transportation, national security, and electronics.

Battelle-Columbus also has extensive research facilities at nearby West Jefferson, Ohio, where nuclear, life sciences, and large-scale, pilot-plant studies are conducted. Other components include Battelle's New England Marine Research Laboratory, Duxbury, Massachusetts, a pioneer in marine biology and ecology studies; the Florida Marine

Research Facility, near Daytona Beach, Florida; and Battelle's Houston Operations, Houston, Texas.

The staff numbers more than 3,000 scientists, engineers, and supporting specialists whose training and expertise embrace the physical, life, social, and behavioral sciences. Research volume at Battelle-Columbus is more than \$120 million a year.

Battelle Memorial Institute, headquartered in Columbus, Ohio, was established by the Will of Gordon Battelle. The Institute has as its broad objective the benefit of mankind by the advancement and utilization of science through a broad range of research, development, and demonstration programs, as well as educational, and invention and technology development activities. In helping to meet the challenges of today, its goal is to advance knowledge through research and other creative scientific activities and to apply that knowledge to improve the quality of life. In addition to conducting sponsored research for others, Battelle maintains its own research, development, educational, and invention-development programs.

Research operations at Battelle began in 1929 with a staff of 30 people. Today, the staff numbers more than 7,100 worldwide and research volume is in excess of \$420 million annually. Battelle operates major research facilities in Columbus, Ohio; Richland, Washington; Geneva, Switzerland; and Frankfurt, Germany. Additionally, it has offices and correspondents in various cities in the United States, Europe, Latin America, Australia, and the Far East.



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